ordinary skill in the art will appreciate that many variations and alterations to the following details are within the scope of the invention. Accordingly, the following preferred embodiment of the invention is set forth without any loss of generality to, and without imposing limitations upon, the claimed invention.

The optical switch system according to embodiments of the present invention switches light from any of a set of input fibers into any of a set of output fibers in a non-blocking fashion (i.e. the ability to switch a particular path is independent of the current configuration of the switch). The switching system is generally built from steering modules. FIG. **3** depicts a steering module according to a first embodiment of the present invention. The steering module **100** generally comprises two 2-dimensional mirror arrays **110**, **130** and relay optics **120** disposed along an optical path between the mirror arrays. The mirror arrays **110**, **130** each typically comprise N×M arrays of single axis mirrors **112**, **132**. Generally N and M are integers greater than one. In the special case of square arrays, N=M.

In the present application, a single axis mirror refers to a moveable mirror configured to rotate about a single axis. Mirrors **112** and **132** rotate about axes **114**, **134** that are different. Typically, mirrors **112** and mirrors **132** rotate about axes **114**, **134** that are substantially orthogonal to each other. For example, mirrors **112** are configured to rotate about axes **114**, oriented in a substantially horizontal plane. Mirrors **132** are configured to rotate about axis **134** oriented in a substantially vertical plane.

An input light beam **101** from a input fiber in a given row and column of an N×M input fiber array (not shown) impinges on a given mirror **112** in array **110**. Mirrors **112** and **132** deflect the light beam **101** towards a fiber in an N×M output fiber array (not shown). Those skilled in the art will recognize that because the propagation of light is reversible, the role of input and output fibers may be reversed.

In an exemplary embodiment, relay optics **120** comprises a first focusing element **122** and a second focusing element **124** in a confocal configuration. For the purposes of this application the "focusing element" encompasses optical elements capable of focusing light. Such elements include refractive elements such as lenses, reflective elements such as mirrors, diffractive elements and micro-optical elements. Lenses include simple lenses and compound, i.e. multiple element lenses, graded refractive index (GRIN) lenses, ball lenses, and the like. Diffractive elements include Fresnel lenses and the like. In a confocal configuration, focusing elements **122** and **124** are characterized by the substantially same focal length f and separated from each other by a distance substantially equal to 2*f*. Furthermore, array **110** is located a distance f from focusing element **122** and array **130** is located a distance substantially equal to f away from focusing element **124**.

Relay optics **120** image mirror array **110** onto mirror array **130**. The angle of beam **101** may be controlled with respect to both axes **114** and **134** by adjusting the angle of the appropriate mirrors in the arrays **110** and **130**. For example, beam **101** emerges from mirror array **110** at an angle $\phi$ with respect to the object plane of relay optics **120**. The object plane of relay optics **120** is typically located proximate mirror array **110**. The image plane of relay optics **120** is typically located proximate mirror array **130**. Relay optics **120** are configured to ensure that beam **101** impinges on the image plane of relay optics **120** at the same angle $\phi$. In other words, light beam **101** enters and leaves relay optics **120** at the same angle. Furthermore, parallel light entering relay optics **120** leaves as parallel light.

Steering module **100** may be used for beam steering in small port-count switches or if loss is not critical. Alternatively, module **100** may be used to switch beam **101** from input fibers in an N×M array to a grid or array of photodetectors. Mirrors in array **110** deflect light beam **101** to the row containing the desired output fiber or detector. Mirrors in array **130** deflect beam **101** to the desired column on that row.

FIG. **4** depicts a steered beam switching system **200** according to a second embodiment of the invention. If the port count becomes sufficiently large on module **100**, large losses may occur due to light entering the fibers at too great an angle. To overcome this, the system **200** that utilizes two modules of the type shown in FIG. **2** to ensure that beam **101** enters the output fiber at the correct angle.

The system **200** generally comprises a first module **210** coupled to an N×M input fiber array **202** and a second module **220** coupled to an output fiber array **204**. Modules **210** and **220** determine, at the plane of output fiber array **204**, the position and angle of an optical beam emerging from any of the input fibers in input fiber array **202**. Modules **210** and **220** have features in common with module **100** of FIG. **2**. Module **210** comprises single axis mirror arrays **212**, **214** and relay optics **216**. Mirrors in arrays **212** and **214** rotate about mutually orthogonal axes. Module **220** comprises single axis mirror arrays **222**, **224** and relay optics **226**. Mirrors in arrays **222** and **224** rotate about mutually orthogonal axes.

In the exemplary embodiment depicted in FIG. **4** mirrors in arrays **214** and **222** rotate about substantially parallel axes. A light beam **201** from a fiber **203** in input fiber array **202** couples to a corresponding mirror **213** in mirror array **212**. Mirror **215** steers light beam **201** to a mirror **215** in array **214**. Relay optics **216** preserve at an image plane the angle that light beam **201** makes with respect to an object plane of relay optics **216**. Mirror **215** deflects light beam **201** to a mirror **223** on array **222**. Mirror **223** steers light beam **201** to a mirror **225** in array **224**. Relay optics **226** preserve at an image plane the angle that light beam **201** makes with respect to an object plane of relay optics **226**. Mirror **225** deflects light beam **201** to a corresponding fiber **205** in output fiber array **204**.

Those skilled in the art will recognize that by suitable manipulation of mirrors **213**, **215**, **223**, and **225** any fiber in input array **202** may be coupled to array fiber in output array **204**.

It will be clear to one skilled in the art that the above embodiment may be altered in many ways without departing from the scope of the invention. For example, although in the above embodiments, the mirrors are described as MEMS mirrors other mirrors such as bulk mirrors or large-area deformable mirrors may be used. Accordingly, the scone of the invention should be determined by the following claims and their legal equivalents.

What is claimed is:

**1**. A beam steering apparatus comprising:

a) a first N×M array of mirrors, wherein N and M are integers and each mirror in the first array is configured to rotate about a single first axis; and

b) a second N×M array of mirrors, wherein each mirror in the second array is configured to rotate about a single second axis;

further comprising at least one photodetector, wherein a signal input to the beam steering apparatus may be steered onto said photodetector,

wherein each mirror in the first or second array may be coupled to a corresponding fiber in an N×M fiber array.